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# The determination of coal dust emission and percentage of quartz in coal dust emission during the cutting anthracite coal by shearing and bottom blade of the plow

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**Abstract**

On the background of topic dust control and reduction in mining a theoretical model of dust origination during processes of mechanical rock cutting was developed. This theoretical model was validated by practical investigation on experimental cutting test equipment. The result of numerous tests by the shearing blade and bottom blade of the plow on the anthracite coal shows a clear relation between the anthracite coal dust appearance and the cutting parameters e. g. rake angle, cutting depth and so on. One of all difficulties in order to determinate of highest pemissible level of anthracite coal dust in the workplace is the exact value of the percentage of quartz is contained in coal dust. So, the dust coal appearance from there tests was received and burned in the oven of laboratory for the German Institute for Standardization (DIN-Deutsches Institut für Normung) in order to determinate the percentage of quartz in coal dust. Finally conclusions for the approaches of dust coal control during process of mechanical anthracite coal cutting are derived and the highest pemissible level of anthracite coal dust in the workplace may be predicted for the prevention of the anthracosis.

*Keywords*: coal dust emission; anthracite coal

## 1. Introduction

Mineral dusts are formed whenever rock is broken by impact, abrasion, crushing, cutting, grinding or explosives. Every time coal is broken from the seam, coal mine dust is generated. It’s also released during blasting, drilling, or transportation. Continuous mining and longwall operations produce massive amounts of coal as well as coal mine dust, come of it respirable.

Black lung is, and has been, a problem for miners. Conditions of workplace have improved but the risk to miners remains. Besides, the coal dusts still have potential fire and explosion when they mix with the air and methane in the underground coal mining [1-3].

Dust article size is displayed by term equivalent dynamic diameter, that is received a value from 0.001 to 100 µm. The effect on the health increases if the size of the particles decreases and becomes significant for particle

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diameters of less than 0.5 µm. Although Brownian motion occurs throughout the respiratory system, it becomes an effective mode of dust deposition only when the mean displacement becomes comparable with the size of the air passage. Hence, it is particularly important in the alveoli and finer bronchioles.

Because the effect of dust on the health still is in dependence on the characterization of material dust therefore the maximum allowable concentration (MAC) of dusts in the workplace are calculated and standardized. However, the determination of standard for all of dusty type is invisible because the mineral dusts aren't only one material dust but they usually are mixed from many materials. On the MAC standard of quartz dust a relation between the quartz dust fraction with the particulate matter diameters less than 10 µm (group A) and dust concentration group A is developed in the figure 1. This diagram show the value of MAC for quartz dust is 0.15 mg/m$^3$ and MAC for the general dust of A-group is 3 or 6 mg/m$^3$. This relation describes that if percentage of quartz dust less than 5% then MAC for general dust is 3 mg/m$^3$. If percentages of quartz dust less than 2.5 mg/m$^3$ then MAC for general dust is 6 mg/m$^3$.

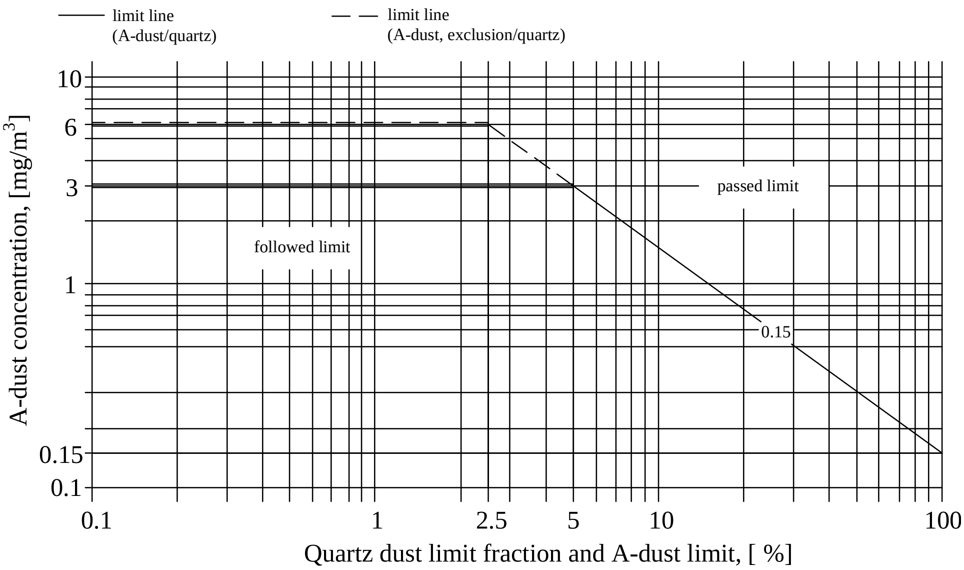


Fig. 1. Diagram of the determination MAC for the quartz dust limit fraction [1]

The determination of MAC for coal dust in the air flow in underground coal mining is very important and necessary in order to enforce the safety and health engineering.

## 2. Mathematical modeling of dust emission in the cutting process

### 2.1. Model development

Up to now cutting models of e.g. Roxborougt & Sen, Whittake & Frith and Whittaker, Singh & Sun are used [4, 5, 6]. The models describe the cutting process as the interaction between the rock and a tool moving parallel to the rock surface. In the case of a brittle rock material coarse grained chips will be generated. The rock chip and the fine grained material are generated when a specific level of cutting force is reached. The input of cutting power influences the chip formation and the shape and occurrence of the dust zone. The coarseness depends on the pressure zone on the cone end of the tool and the cutting depth.

One part of the total generated dust volume is transported on the surface of the generated chip particles. Another part is dispersed in the air and some of the dust volume remains on the rock surface.

Figure 2 shows the model of dust emission during the chip formation process. Two zones are distinguishable. The shape and occurrence of the first zone, so called dust or milling zone depends on the value of the feed component $F_C$ of the total cutting force. The second zone is the crushed area below the milling zone. Responsible for the formation of the zone is the normal component $F_N$ of the cutting force transferred by the outside face of the cutting tool [7, 8].

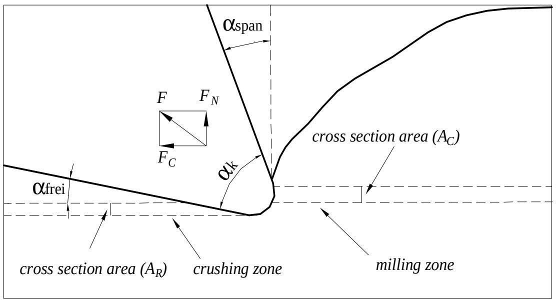


Fig. 2. Model of dust emission zones in the cutting process
*$a_{span}$ – rake angle; $a_{frei}$ – clearance angle; $a_k$ – cone angle;*
*$F_N$ – normal force; $F_C$ – cutting force; F – resultant cutting force.*

The dust volume percentage (DVP) $Q_S$ of one cut was calculated under application of the following equation:

$$Q_S = 100 \cdot \frac{DustVolume(V_S)}{TotalCuttingVolume(V_M)} = 100 \cdot \frac{A_C + A_R}{A_M}, \%$$

$V_S = V_C + V_R$ - dust volume in [mm³];
$V_C = A_C \cdot S$ - Dust volume in dependence on the feed component of the cutting force in [mm³];
$V_R = A_R \cdot S$ - Dust volume in dependence on the normal component of the cutting force in [mm³];
$V_M = A_M \cdot S$ - Total cutting volume, mm³;
$A_C$ - Cross section area of the milling zone in [mm²];
$A_R$ - Cross section area of the crushed zone in [mm²];
$A_M$ - Total cross section area in [mm²];
$S$ - Cut length in [mm].

### *2.2. Calculation of dust emission for cone bit*

The DVP $Q_{SK}$ for a partially blocked cut can be calculated with the following equation:

$$Q_{SK} = 100 \cdot \frac{n_s \cdot \frac{16 \cdot \pi \cdot \sigma_t^2 \cdot d^2}{\sigma_c^2 \cdot \cos^2 \alpha_k} + n_s \cdot A_{RK}}{n_s \cdot d^2 \cdot \tan\theta_s - (n_s - 1) \cdot (d - l \cdot \cot\theta_s) \cdot \tan\theta_s}, \%$$

$n_s$ – parallel cutting paths; $\sigma_t$ – Tensile strenght [MPa]; $\sigma_c$ – Uni-axial compression strength [MPa]; $\alpha_k$ – Cone angle [°]; $d$ – Cutting depth [mm]; $\theta_s$ – Breakout angle [°]; $2l$ – Cutting path distance [mm]; $A_{RK}$ – Cross section area of the crushed zone [mm²].

The experimental DVP $Q_{exK}$ can be calculated with the following equation:

$$Q_{exK} = k_K \cdot Q_{SK} = k_K \cdot \left( \frac{A_{CK} + A_{RK}}{A_{MK}} \right) \cdot 100, \%$$

$A_{CK}$ – Cross section area of the milling zone for cone bit [mm²];

$A_{MK}$ – Total cross section with $n_s$ parallel cutting paths.

If the clearance angle achieves its maximum the cross section area $A_{RK}$ is defined as 0. That means a minimum of contact area between cutting tool and rock surface. An experimental coefficient $k_K$ is introduced that characterizes the dust emission of a grain size < 125 µm. The correlation between the coefficient $k_k$ and the DVP is described by the following equation:

$$Q^{0}_{exK} = k_K \cdot Q_{SK} = k_K \cdot \frac{\frac{16\cdot\pi\cdot\sigma_t^2\cdot d^2}{\sigma_c^2\cdot\cos^2\alpha_k}}{\frac{A_{MK}}{n_s}} \cdot 100\ ,\ \%$$

$$Q^{\infty}_{exK} = \frac{k_K\cdot A_{CK} + k_K\cdot A_{RK}}{\frac{A_{MK}}{n_s}}\ ,\ \%$$

$Q^{0}_{exK}$ is the DVP on the maximum point of the clearance angle and $Q^{\infty}_{exK}$ is the DVP in dependence of the decreasing clearance angle

## 3. Method of burning coal dust samples

The researches for anthracite coal dust showed the coal dust always contain particle quartz dust. The figure 3 represents an image of the particle quartz in anthracite coal dust sample [9].

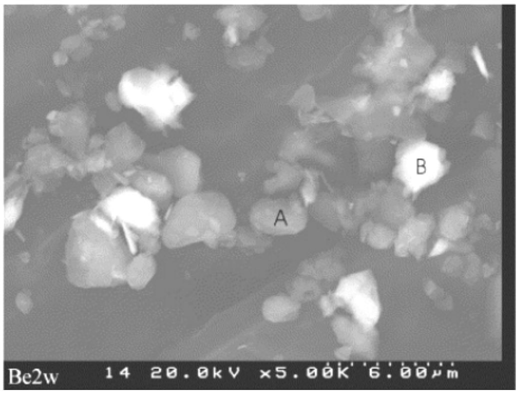


Fig. 3. Representation of particle quartz in anthracite coal dust: A – Coal particle; B – Quartz particle

However those method could'n detemine the percentages of quartz dust in coal dust sample.
A solution for this problem is the combustion of the coal dust in an oven for DIN 51719 of Germany [10]. The coal dust sample with the grain < 125 µm is burned until the level of mass permanence by the temperature (810 ± 10) °C. The rest after combustion of coal dust is really the quartz mass consisted in the coal dust sample. This method is relized step by step following:

### *3.1. Preperation for the experiment*

The preperation for the experiment included the equipments of the weight and sample:

- A analytical balace with a correction in 0.1 mg;
- The pot by the quarzglas, porcelain or platinum with the high from 8 to 10 mm, the wide and the length had to set up in order to 1 cm$^2$ of bottom pot obtains not more than 0.15 g coal dust;

- The plate by ceramical or thermodurical material in the 6 mm thickly. Its size has to set up early into burn oven;
- Internal temperature of the oven has to conserve in (815 ± 10) $^oC$;
- A desiccator;
- The coal dust samples were prepared for DIN 51701-3 of Germany [11].

### *3.2. Calculation of the percentage of quartz dust in coal dust sample*

The percentage of quartz dust of coal dust sample after burn is calculated for following equation [10]:

$$A = \frac{m_3 - m_1}{m_2 - m_1} \cdot 100\ , \%$$

Where:
$A$ – Percentage of the quartz dust, %;
$m_1$ – Mass of the pot without coal dust, g;
$m_2$ – Mass of the pot with coal dust, g;
$m_3$ – Mass of the pot with quartz dust, g.

## 4. Case study

On the background of the rock cutting process a theoretical model of dust emission is developed in order to calculate the dust emission during rock cutting by the difference tools [7,8,12,13].

The anthracite coal dust samples are received during the anthracite sample cutting by shearing and bottom blade of plow. The experiments are realized in institute for mining and civil engineering at technical university Bergakademie Freiberg, Germany.

### *4.1. Test cutting equipment*

The technical labs of institute for mining and civil engineering at technical university Bergakademie Freiberg has already a test cutting station HKS 800 x 1000 in order to research the practical determination of the cutting.

The test of cutting station is equipped with a force sensor to measure and record the 3 components of the cutting force acting on the cutting tool during the cut. The components of the cutting force are the feed $F_{C,}$ side $F_S$ and normal component $F_N$ [14].

The outside machine support carries a flat chisel to level and prepare the rock surface for the subsequent cutting force analysis under application of the force sensor. The came rack can be used to install other tools.

Additional to the natural rock samples of concrete (made of cement and sand or limestone) were produced with defined dimensions of 60 x 40 x 20 cm (length x width x high). The cut length is 40 cm. The natural rock e.g. anthracite was encased in concrete to reach the required dimension for the sample mount and to prevent any material de-compression. The foil cover around the rock sample was applied to collect and measure the entire chip colume of the cut.

To maintain the complete interception of fine and coarse-grained dust it was necessary to modify the already existing dust filter and test different filter materials. One precondition of the filter selection was the flammability of the filter material due to the approach of dust measurement. The filter material and the coal dust inside were combust until the level of mass permanence was reached. In this way were measured the quartz content of the coal.
The practical tests include the application of different tools as two plough tools namely a bottom blade and a shearing blade. They used to apply to extract hard coal for longway mining in underground coal mining. The bottom blade is type MK97-100N/VS and the shearing blade is type MK97-002-VS. They are manufactured by Schmalkalden BmbH & Co. KG.

### 4.2. Test parameter

The lab test on the test cutting station varied the following cut parameters:

- Material cutting: anthracite coal;
- Tool geometries and tool arrangement: rake angle = $0^o$; $7.5^o$ and $15^o$ for bottom and shearing blade of plow;
- Cutting speed: 0.25 m/s;
- Cutting depth: d = 3 mm, 6 mm and 9 mm;
- The cutting path interspaces *l*, which depends of the cutting depth $2l = 2d$.

## 5. The results of test and conclusion

The relation between the average percentage of quartz dust and cutting parameters is showed in figure 4 for the bottom blade and figure 5 for the shearing blade of plow.

The theoretical models of the dust emission during the natural hard rock cutting showed that, the mineral dust emission in dependence on the tool geometries, the cutting speed and the depth cutting [8,12,13]. However they are depended upon the parameters of cutting sample e.g geotechnical structure, mass strength and humidity. The dust emission during natural rock cutting in laboratory can be more than during that rock cutting in fact because the environmental condition for test cutting in labs wasn't entire simultaneous on fact. But the correction of this error is up to now very difficult.

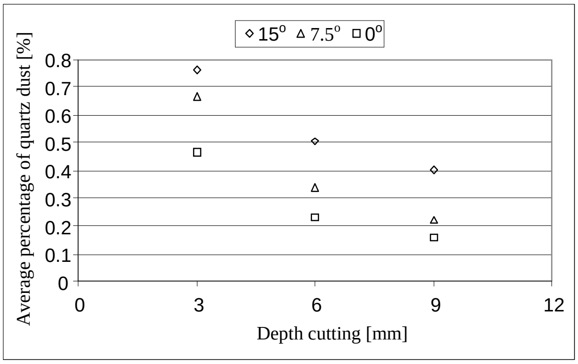


Fig. 4. The average percentage of quartz dust for the bottom blade of plow depends on the rake angle and the depth cutting tools [20]

Figures 4 and 5 show the percentage of quartz dust emission in dependence on the rake angle and the depth cutting. If the rake angle is increased, then the percentage of quartz dust emission increases too. But if the depth cutting is increased, then the percentage of quartz dust emission decreases.

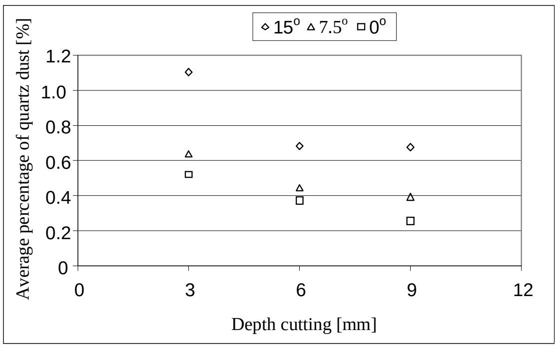


Fig. 5. The average percentage of quartz dust for the shearing blade of plow depends on the rake angle and the depth cutting tolls [20]

Nevertheless, the results of test are showed that, the percentage of quartz dust emission by rake angle $0^o$ and depth cutting 3 mm is largest and it is the value from 0.6 to 1.2%. If the depth cutting increases 3 times, then the percentage of quartz dust emission decreases from 30 to 50%. Nowadays, the blade of plow can cut to depth from face end to face end from 35 mm for hard coal and to 150 mm for weak coal, so the percentage of quartz dust emission in fact is less than in labs test.

On the results of test can conclude that, the coal dust with particles < 125 µm consist of the excavation by plow in longwall mining contained the percentage of quartz dust less than 2.5%. The determination of the MAC of mineral dust represented in the figure 1 can be applied for hard coal dust is 6 mg/m$^3$ or as general dust (10 mg/m$^3$). However the MAC of coal dust in the turn air of underground coal mining has to consider more another factors e.g. the quality of intake air, coal rank, coalseam, stratums and so on.

## References


[1] Steinbruchs-Berufsgenossenschaft. Mineralischer Staub, 2004.

[2] E.U. Reuther, Lehrbuch der Bergbaukunde mit besonderer Berücksichtigung des Steinkohlebergbaus, 1989.

[3] U. Koller, Kleine Partikel mit großer Wirkung. Mai 2005.GSF – Forschungszentrum für Umwelt und Gesundheit, 2005.

[4] C.R. Fairhurst, Theory and practice of enhances rock cutting picks: the water jet assisted tool and the vibrating tool. Thesis L'Ecole nationale superieure des mines de Paris, 1987.

[5] F.F. Roxborough and G.C. Sen, Breaking coal and rock. In. C.H. Martin (ed.) Australian coal mining practice, AIMM Monograph Series, 1986.

[6] B.N. Whittaker, R.N. Singh and G. Sun, Rock fracture mechanics. Amsterdam: Elsevier, 1992.

[7] V.P. Quang, C. Drebenstedt, Mathematische Modellbildung für die Staubentstehung beim Spannsvorgang des Gesteins. Freiberger Forschungsforum 58. Berg- und Hüttenmännischer Tag, 2007.

[8] V.P. Quang, Beitrag zur Staubentstehung und –verhütung bei spanender Gesteinszerstörung. TU Bergakademie Freiberg. Germany, 2007.

[9] S. Shi, C.W. Hong, T. Philip and X. Sheng, Characteristic of coal mine ventilation air flows. Journal of Environmental management, 2006.

[10] DIN 51719. Prüfung fester Brennstoffe. Bestimmung des Aschegehaltes. Deutsche Norm, 1997.

[11] DIN 51701-3. Prüfung fester Brennstoffe. Probenahme und Probenvorbereitung. Durchführung der probenvorbereitung. Deutsche Norm, 1997.

[12] C. Drebenstedt and V.P. Quang, Dust emission in dependence on cutting parameters in the process of mechanical rock destruction. Mine Planning and Equipment Selection and Environmental Issues and Waste Management in Energy and Mineral Production. 11 (2007) 285-294.

[13] V.P. Quang and C. Drebenstedt, The formation of dust depending on the cutting parameters during the destruction of rock by cutting. Mine Planning and Equipment Selection and Environmental Issues and Waste Management in Energy and Mineral Production. 9 (2007) 651-662.

[14] P. Sitz and D. Scheffler, Gesteinsuntersuchungen für den Gewinnungs- und Zerkleinerungsmaschinenbau. Institut für Bergbau der TU Bergakademie Freiberg, 1998.